Guide for Surveying PHREATOPHYTE *Vegetation*

Agriculture Handbook No. 266

U.S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

FRONTISPIECE.—Dense fivestamen tamarisk nearly hides an old trail on the flood plain of the Gila River near Buckeye, Ariz. (U.S. Geological Survey photo W-58-155.)

Guide for Surveying PHREATOPHYTE *Vegetation*

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ACKNOWLEDGMENTS

An evaluation of the kinds and amounts of vegetation in any specific area is a prerequisite to the preparation of plans for its suppression or conversion. It is highly desirable to standardize procedures for surveying and mapping bottom-land and stream-bank vegetation. Recognizing these facts, the Phreatophyte Subcommittee of the Pacific Southwest Inter-Agency Committee sponsored the development of standard methods. The work started in November 1956 with the organization of a Task Force by the Phreatophyte Subcommittee.

Representatives of the Subcommittee who have served on the Task Force are H. R. McDonald and O. J. Lowry, U.S. Bureau of Reclamation; T. W. Robinson, U.S. Geological Survey; J. S. Horton, U.S. Forest Service; and C. B. Thompson and J. G. Koogler, State of New Mexico.

This handbook was prepared by the coauthors, who acknowledge with gratitude the assistance of the other members of the Task Force, members of the Phreatophyte Subcommittee, and many other individuals who have reviewed the manuscript and offered constructive suggestions for improvement.

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GUIDE FOR SURVEYING PHREATOPHYTE VEGETATION

J. S. Horton,[1] T. W. Robinson,[2] and H. R. McDonald[3]

INTRODUCTION

In the arid and semiarid region of the Western United States, water losses from stream channels, flood plains, bottom lands, and delta areas are serious. A part of this loss is caused by evaporation from water surfaces and moist soil, but wherever ground water is within reach of plant roots, a heavy loss also results from transpiration (Robinson, 1958).[4] Plants whose roots can reach ground water are called phreatophytes. In this region, most water comes from the mountains and moves long distances in streams whose banks are often lined with trees and shrubs. In the valleys, ground water in alluvial deposits may be tapped by deeply penetrating roots.

On the flood plains and in overflow channels many tree and shrub species grow in dense thickets and produce branches close to the ground. As a result stream velocities during overflow periods are reduced, and sediment deposits raise the level of the stream channel and reduce its capacity to carry flood flows. Even though the sediments are prevented from entering storage reservoirs, a serious flood hazard to surrounding lands is created.

In spite of water losses and creation of additional flood hazards, vegetation growing along streams or on flood plains may have considerable economic value. Increasing recreational use along streams may place a high value upon these trees and shrubs. In still other areas, grazing and wildlife use of the streamside vegetation is important. Also, vegetation may be desirable to protect the streambanks from erosion, particularly during floods.

If the vegetation tapping ground water can be changed to a type that uses less water, water for irrigation and other beneficial uses could be salvaged. Decreasing the present cover or establishing a cover of plants that use less water should bring about the desired objectives. Substitution of a species with more economic value or finding uses for the existing species would be a form of salvage that would help compensate for present water losses.

To properly manage bottom-land and streambank areas and to evaluate the overall effects of vegetation treatments, surveys are needed to determine the kinds of plants present in the existing stands, the relative importance of component species, and such characteristics of the vegetation as percentage of the ground covered by living plants, average height and crown thickness of the trees and shrubs, and the amount of understory vegetation.

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[4] Names followed by dates refer to Literature Cited, p. 37.

RECOMMENDED PROCEDURE FOR SURVEYING PHREATOPHYTES

This handbook presents a survey procedure based upon random samples that can be tested for statistical reliability. It is concerned principally with surveys designed to collect information that can be used as a basis for management of vegetation along river or stream reaches. In most cases the primary purpose of this management will be to reduce uneconomic water losses. However, it is not the purpose of this publication to describe methods used in computing water loss from data on vegetation cover. The most frequently applied method, based on the relation of water loss to foliage volume, was developed by Gatewood et al. (1950). No better method is yet known, though the validity of the procedure has been challenged (Colman, 1953).

The procedure outlined in this guide for phreatophyte surveys is based upon the determination of crown cover, height of trees and shrubs, and depth of crown by use of randomly selected sampling lines (Canfield, 1942[5]). The statistical procedures, however, are based solely upon estimation of crown cover within prescribed limits of precision. Height of trees and shrubs and depth of crown are obtained from the survey data, but no estimates of precision for these data are attempted.

To aid understanding of the recommended procedure, a model survey is used for illustrative purposes in this handbook. The model was developed on the basis of actual conditions and vegetation data, but many adjustments were made in the data to illustrate important relationships.

Seven steps suggested for a survey of phreatophyte vegetation are:

1. *Determine the area to be surveyed and the necessary area breakdowns. Assemble aerial photographs for the entire survey area and familiarize all workers with the species and vegetation types involved.*
2. *Prepare, in the office, preliminary vegetation maps of the survey area from aerial photographs, with later refinements of type boundaries by observation from aircraft.*
3. *Determine number of sampling lines needed to achieve desired precision by a preliminary field survey and applying the data to a nomograph.*
4. *Develop a sampling system with random selection of the sampling lines.*
5. *Collect field data from the randomly selected sampling lines and permanently mark these lines for future surveys.*
6. *Determine reliability of the field data by use of standard statistical methods.*
7. *Summarize the data in a form best suited to achieve the purposes of the study.*

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[5] Available from the Rocky Mountain Forest and Range Expt. Sta., Fort Collins, Colo.

Preliminary Considerations

Before the actual job of surveying starts, the workers should become thoroughly familiar with the area and the vegetation to be surveyed. Time should be spent both in the field and in studying aerial photographs.

Organization Into Survey Units

The area to be surveyed should be carefully delineated and it should be decided whether to handle the entire area as one survey or whether to divide the area into sections. In larger river surveys it will be desirable to divide the area for ease in handling the data.

Aerial Photographs

A set of recent aerial photographs should be obtained for the entire survey area. The scale should depend on the intensity of the survey. For detailed surveys, approximately 6 inches to the mile (1:10,000) is preferable. Many less intensive surveys have satisfactorily used photos with a scale of 4 inches to the mile (1:15,840). In any scale, the photographs must have good contrast.

Determination of Species

All workers must be familiar with the important tree, shrub, and herbaceous species and their identification at various growth stages. This is especially true where similar species, such as seepwillow baccharis (*Baccharis glutinosa* Pers.)[6] and the true willow (*Salix* spp.) occur associated in the area. Robinson (1958) gives information to aid workers in identification of principal phreatophytes. More detailed descriptions may be found in Benson and Darrow (1954), Little (1950), or any available reference flora of the State or region in which the study area is located, such as Kearney and Peebles (1951) for Arizona and McMinn (1959) for California.

Preliminary Mapping of Types

Aerial photographs are excellently suited for use as base maps. On the photographs distinct areas of vegetation types and densities can be delineated with little difficulty before beginning fieldwork.

Office Mapping of Types on Aerial Photographs

The area to be surveyed should be outlined on the aerial photographs. A satisfactory series has overlapping photographs. The centers of the photographs should be used for mapping, eliminating the distorted outer edges. The portion to be used should be marked on the photographs before any mapping is done.

Boundary lines between areas that appear distinct should be drawn in the office even if species cannot be identified. Use of a stereoscope will help in many instances. Separation into major vegetation types, such as grass and brush, can be made readily. Differences in other major species and outstanding density variations can also be detected and type boundaries drawn.

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[6] Common and scientific names of all plants mentioned in this handbook follow Kelsey and Dayton (eds.). Standardized plant names. Ed. 2. 1942.

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Recommended standards for the smallest area to be mapped are as follows: At a scale of 6 inches to the mile, an area one-eighth inch on a side equals a little over a quarter of an acre; at a scale of 4 inches to the mile, an area one-eighth inch on a side equals about two-thirds of an acre.

Figure 1, originally an aerial photograph of the model survey area, illustrates the type separations that can be made in the office. The following generalized types have been distinguished and mapped:

1. Arid slopes outside phreatophyte zone.
2. River channel.
3. Open, fourwing saltbush (*Atriplex canescens* (Pursh.) Nutt.) with a few widely scattered mesquite (*Prosopis* sp.).
4. Open, with scattered large mesquite.
5. Open, low-density cover. Arrowweed pluchea (*Pluchea sericea* (Nutt.) Coville) is the principal dominant.
6. Medium-density fivestamen tamarisk (*Tamarix pentandra* Pallas) with some seepwillow.
7. Dense cover of tamarisk.

Refinement of Type Boundaries

After distinct cover types and any outstanding differences in density of cover are delineated on the aerial photographs, surveys should be made in the field to determine species composition and to check the estimates of relative crown cover percent. Workers should do sufficient fieldwork by car to become familiar with the types and species. An aerial survey then should be made to check the office mapping. Further subdivisions are often necessary because differences between important species do not always show clearly on the photograph. Occasionally, consolidation of two types separated in the office will prove desirable.

A helicopter has decided advantages over a fixed-wing aircraft because it can hover, change direction, and approach the ground as desired. The observer should have the photos well oriented and should indicate on the photos the species and relative density of each delineated area. Changes in boundary lines of the previously mapped types should be indicated if necessary.

With fixed-wing craft, the procedure is the same, but it is more difficult to observe accurately because of the continuous forward movement of the plane. The flight starts at the upper end of the area and follows a series of slow horizontal overlapping loops or spirals over the area, each succeeding spiral being a little farther downstream. The plane is flown at as low an altitude as is consistent with safety—usually between 50 and 100 feet above the top of the vegetation. If the observer cannot complete the information about an area on one pass of the plane, he will have a second and perhaps a third opportunity on the succeeding spirals.

In our model survey, five vegetation types were delineated on the aerial photograph on the basis of species and density. During the aerial survey some changes were made. The following list compares the new arrangement of vegetation types with the system of numbers used in figure 1 and the accompanying description.

Figure 2 illustrates the comparatively minor changes needed as a result of the aerial survey. Mesquite (No. 4) was divided into two

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FIGURE 1.—Aerial photograph with type boundaries mapped in the office. Two straight east-west access roads are visible. (Original photograph by Pecos River Commission.)

Vegetation types and subtypes	*Type numbers used in figure 1*	*Type numbers after aerial survey*
Saltbush	3	3
Mesquite:		
Open	------------	4A
Dense	4	4
Arrowweed:		
Open	5	5
Dense	------------	5A
Tamarisk:		
Medium	6	6
Dense	7	6
Tamarisk-seepwillow	------------	8

density subtypes (Nos. 4 and 4A) and some of the open subtype (No. 3) added to the open mesquite (No. 4A). Arrowweed (No. 5) was also divided into two density subtypes (Nos. 5 and 5A) and parts of other types had sufficient arrowweed to be separated. The two tamarisk density subtypes (Nos. 6 and 7) appeared by aerial survey to be so similar and so difficult to separate that they were combined into one type (No. 6). Because of the large amount of seepwillow observed during the aerial survey in some of the tamarisk area, a tamarisk-seepwillow type (No. 8) was separated from the tamarisk subtypes (Nos. 6 and 7).

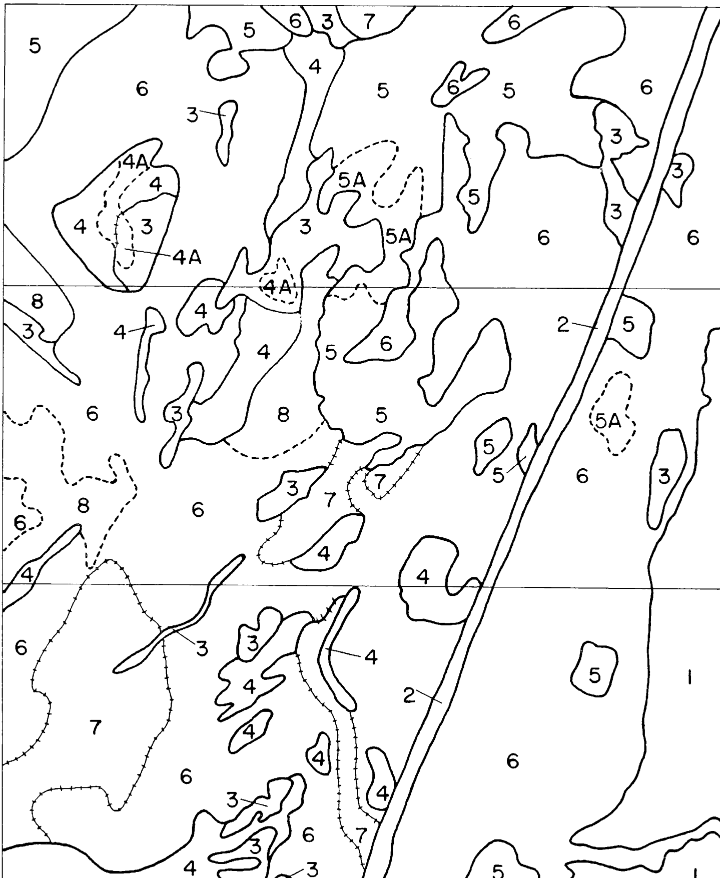

FIGURE 2.—Changes in type boundaries as shown in figure 1 necessitated by the aerial survey and inspection on the ground. New boundaries are shown by dashed lines. Eliminated boundaries are crossed out.

Determination of Random-Sampling Procedure

Each of the phreatophyte types and subtypes delineated on the aerial photographs must be further studied to determine species composition, crown cover, vegetation height, and crown depth. Each of the types must be sampled independently by making measurements at randomly selected locations within each type, using a suitable measurement method.

The Line Intercept as a Basis for Sampling

Many methods of measuring vegetation (Phillips, 1959) are useful, but no other appears as universally suitable for the measurement of phreatophytes as the line-intercept or line-interception method (Canfield, 1942). The degree of precision varies with the intensity of sampling; the more locations for line sampling, the greater the precision. It should be borne in mind that all vegetation sampling has certain limitations that are inherent in individual observations. However, the line-intercept method minimizes the differences between observers and permits close reproduction of results in resurveys of the same degree of precision.

The line-intercept method is based on measurement of the intercept of all plants occurring on randomly located lines of predetermined length. One hundred feet is a convenient length in open cover, but in dense and shrubby vegetation 50-foot lines may be preferable. A tape of the desired length is stretched horizontally either on the ground or as close to the ground as possible. In stands of shrubs less than 5 feet in height, the tape can be stretched on top of the canopy. Permanent stakes should be driven at both ends of the line to provide for resurvey in subsequent years to determine vegetation changes.

The vertical projection of the crown in any shrub is measured to the nearest foot. The summation of the vertical projections equals the crown intercept in percent if a 100-foot base distance is used. The canopy of a shrub is considered solid within the perimeter of the outer branches. If adjacent shrubs have interlocking branches, the canopy is considered closed and is indicated as complete cover. If these adjacent shrubs are different species, the workers have two choices. The distance on the tape dominated by two species with intertwining branches may be marked as occupied by the two species, or a dividing line may be estimated about midway through the area in common and one portion credited to one species and the other portion credited to the other. Only definite openings are to be marked as without shrub cover.

Establishment of Preliminary Lines for Application on Nomograph

The number of lines needed to sample any vegetation type to a desired precision can be estimated by use of a nomograph (fig. 3),[7] designed for this purpose by P. M. Ford of the U.S. Bureau of Reclamation, Denver, Colo., using a method of analysis proposed by Lord (1947). To obtain data for use with this nomograph, ground cover

[7] Copies of this nomograph are available from the Director, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

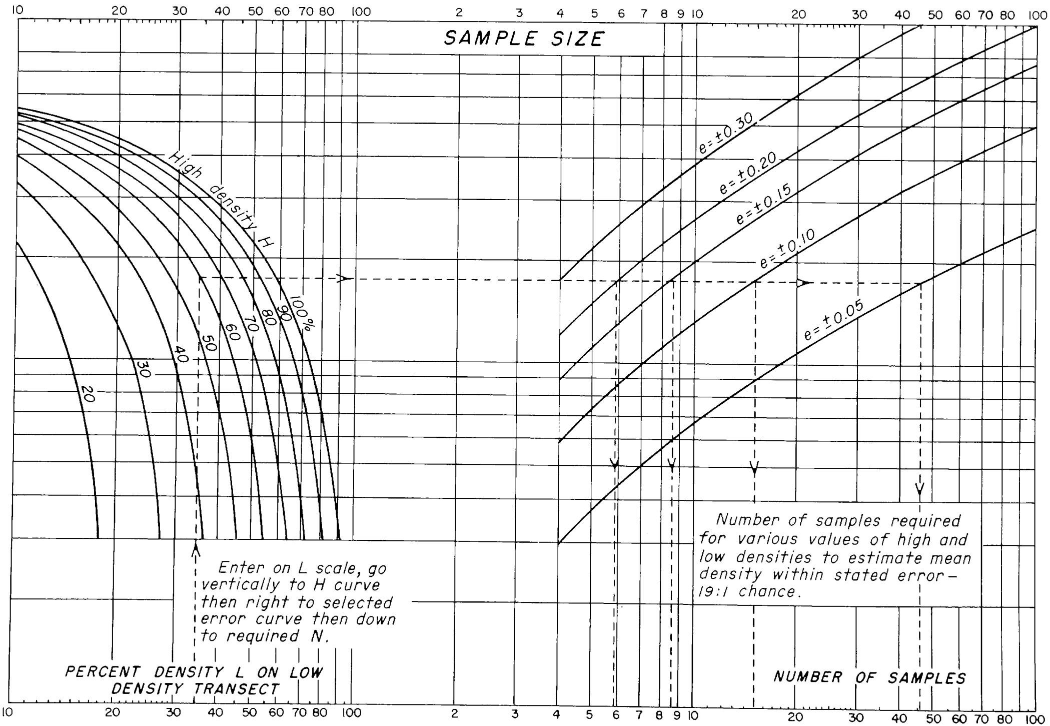

FIGURE 3.—Nomograph for determination of number of lines to obtain specified degree of precision. (U.S. Bureau of Reclamation graph.)

is measured on several preliminary 100-foot lines selected to sample the extremes of cover conditions occurring within the type, from the most open to the densest cover.

The nomograph is not limited to use with line intercepts established to measure cover density or crown-cover percent; rather it can be used for any sampling procedure in predetermining the number of sampling plots or points necessary to approximate a specified precision.

If it is desired not to use the nomograph to determine the number of lines needed, an alternate method would be to start the field survey by measuring an arbitrary number of sampling lines (perhaps 10 for each type), randomly selected by the procedure described under Selection of Sample Points, page 12. The statistical tests explained under Reliability of the Data, page 22, would be applied to the data from these lines to determine the number of extra samples needed to obtain the desired precision. A second field survey would then be made to measure the additional randomly selected lines. In comparison with this alternate method, use of the nomograph should have definite advantages in making it possible to plan and execute the major job of surveying the vegetation in one stage.

To determine the number of lines by use of the nomograph, the type considered is studied carefully on aerial photographs to select the most open as well as the densest areas. Three or more 100-foot lines are measured in the open areas and an equal number of lines in areas of dense cover. The only data to be recorded are the intercepts of the principal species. These preliminary lines must not be included in the random-sampling survey to be carried on in the next stage.

In our model survey, six preliminary lines (three dense cover and three open) were established in each of the seven types and subtypes determined after the aerial survey. Table 1 shows the percent of crown cover measured on the preliminary lines.

TABLE 1.—*Crown cover measured on the preliminary line-intercepts in the seven vegetation types and subtypes of the model survey. Highest and lowest densities in each column are in italics*

Line No.	Tamarisk	Tamarisk-seep-willow	Arrowweed		Mesquite		Salt-bush
			Open	Dense	Open	Dense	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	81	45	58	81	*60*	*55*	*81*
2	52	40	27	49	55	92	26
3	*38*	*35*	29	*47*	40	93	67
4	*90*	90	*65*	80	*23*	59	70
5	64	*98*	61	*99*	32	*96*	*16*
6	89	90	*21*	52	53	62	25

In the types dominated by one woody species, crown cover of all woody species is combined. Almost all such types will have minor species occurring in too small amounts to allow for statistical analysis. In surveys dealing with determination of water use by the vegetation, these species can be assumed to use approximately the same amount of water as the dominant one. It is best, therefore, to analyze total cover as a unit rather than analyzing only the coverage of the dominant species.

In types which have two or more principal species, the total crown cover should be listed as well as that of the principal species. The two principal species of the tamarisk-seepwillow type in the model have been handled separately and are listed below.

Line No.	Crown cover (percent)			
	Tamarisk	Seepwillow	Other species	All species
1	35	*10*	0	45
2	15	20	5	40
3	*10*	25	0	*35*
4	35	*50*	5	90
5	*75*	20	3	*98*
6	45	45	0	90

Determination of Number of Sampling Lines From the Nomograph

To use the nomograph, the procedure would be as follows for a type with the low cover percentage determined by the preliminary survey as 35 percent and the high as 60 percent:

Using first the left-hand set of curves in figure 3, follow the dashed line up from the 35 percent figure on the low-density scale until the 60 percent curve is intersected. Then follow the horizontal dashed line to the right to the desired "e" curve. If a precision of ± 0.05 (5 percent of mean) is desired, read down from the $e= \pm 0.05$ curve to the base scale where it is indicated that 46 samples would be needed. The $e= \pm 0.10$ curve indicates that 15 samples are needed, the ± 0.15 curve shows that 9 samples should be used, and 6 would be required for a precision of ± 0.20. However, in order to get a reasonable estimate of the variation, at least 15 lines should always be used in each type.

If a vegetation type has a great range between high and low crown-cover percentages, more sampling lines are needed. For instance, the preliminary lines for tamarisk (type 6 in our model) showed a range from 38 percent to 90 percent, and in consequence 29 lines would be needed for a ± 0.10 precision, and 10 for a ± 0.20 precision.

Applying the information obtained from the preliminary sampling lines in table 1 to the nomograph, the number of lines needed for the three degrees of precision are determined and entered in columns 1 to 3 of table 2.

The next step is to decide on the precision goal. Ten percent precision is desirable, but because of financial limitations this reliability, requiring 263 sampling lines, cannot be attained.

Inasmuch as the types and subtypes vary in total acreage, some are more important than others. Likewise, an open type would not utilize as much water as the thicker covers. Consequently, area and cover percentage are factors that can be used to adjust the figures obtained from the nomograph to derive a more realistic balance of sampling. Many ways could be devised to aid in determining the desired precision, but the following method is suggested as giving reasonable weight to the various factors.

TABLE 2.—*Information needed to decide upon number of lines to use in random sampling*

Vegetation type	Lines needed for precision of—			Fraction of area [1]	Mean crown cover [2] percent	Importance index [3]
	10%	15%	20%			
	(1)	(2)	(3)	(4)	(5)	(6)
Tamarisk	29	15	10	0. 35	65	22. 75
Tamarisk-seepwillow	38	19	13	. 10	65	6. 50
Arrowweed:						
Open	43	21	14	. 20	45	9. 00
Dense	24	13	9	. 15	70	10. 50
Mesquite:						
Open	33	17	11	. 05	45	2. 25
Dense	15	9	6	. 10	75	7. 50
Saltbush	81	36	22	. 05	50	2. 50
Total	263	130	85	1. 00	--------	61. 00

[1] Estimated or measured from aerial photographs.
[2] Estimated from the preliminary line intercepts in table 1.
[3] Importance index equals area times crown cover.

Column 4 of table 2 gives the areal extent of the component types in our model area, expressed as decimal fractions. These figures are estimates derived from a study of the aerial photographs. Tamarisk covers roughly 35 percent of the area; tamarisk-seepwillow 10 percent of the total area, etc.

Column 5 gives for each type a figure of mean crown cover, which is approximately the midpoint between the high and low values of the line intercepts in table 1.

These two figures are multiplied together to give an importance index (column 6), which is used in table 3 to list the types in order of importance. Based on this importance index, each type is assigned a selected precision which allows a larger error as the type becomes less important.

The selected precision figure is then applied to the number of sampling lines given in table 2 for varying degrees of precision. It is thus determined that tamarisk needs 29 lines for 10 percent precision; dense arrowweed 20 lines for the selected 12 percent precision, etc.

The last column of table 3 lists the finally selected numbers of lines. The number of sampling lines for tamarisk has been raised to 40 because of the importance of this type. The number of lines for tamarisk-seepwillow has been set at 20. It was recognized that this number would not sample the individual species to the precision indicated for the type, but because the two species are similar as to water use and because the type occupied a relatively small area, it was not felt that a higher number was justified.

The number of lines to be measured in each of the mesquite subtypes has been raised to 15 to obtain a reasonable estimate of variability. The total of 160 lines is within the financial limits of the model survey.

TABLE 3.—*Determination of number of sampling lines*

Vegetation type	Importance index	Selected precision [1]	Needed lines [2]	Selected number of lines
Tamarisk	23	10	29	40
Dense arrowweed	11	12	20	20
Open arrowweed	9	13	30	30
Dense mesquite	8	14	10	15
Tamarisk-seepwillow	7	15	19	20
Open mesquite	3	20	11	15
Saltbush	3	20	22	20
Total				160

[1] Based on the importance index.

[2] Number of lines needed to obtain selected precision, from table 2, columns 1 to 3.

It must be borne in mind that the number of lines determined by this method only approximates the actual number of lines needed for a desired reliability. The line-intercept data collected by random sampling must always be checked for reliability by the statistical methods subsequently described.

Selection of Sample Points

Before starting the actual collection of field data, a random sampling system must be set up. Each of the adjusted vegetation types and subtypes decided upon in the preceding section must be sampled separately. Also, in deriving the sampling procedure, the entire area of the type within the survey unit must be considered. Figure 4 outlines the model survey unit including about 7 miles of wide flood plain. All of the phreatophyte area is to be sampled. The rectangles show the limits of the aerial photographs needed to cover the phreatophyte area. The photograph in figure 1 covers section 4 in figure 4.

Overlays that show changes or corrections made after the first office mapping of types should be prepared for each of the aerial photographs. Figure 5 shows the overlay derived for our model, with type boundaries drawn according to the corrections in figure 2.

Standard Procedure

To be statistically sound, a sampling procedure must be set up in such a way that every part of the area to be studied has an equal chance of being chosen. Wherever possible, this concept should be put into practice. A typical standard procedure for random sampling is outlined in the following steps, using the model area as an example.

1. Obtain a table of random numbers. Such a table appears in Snedecor (1956 and earlier editions), and in U.S. Department of

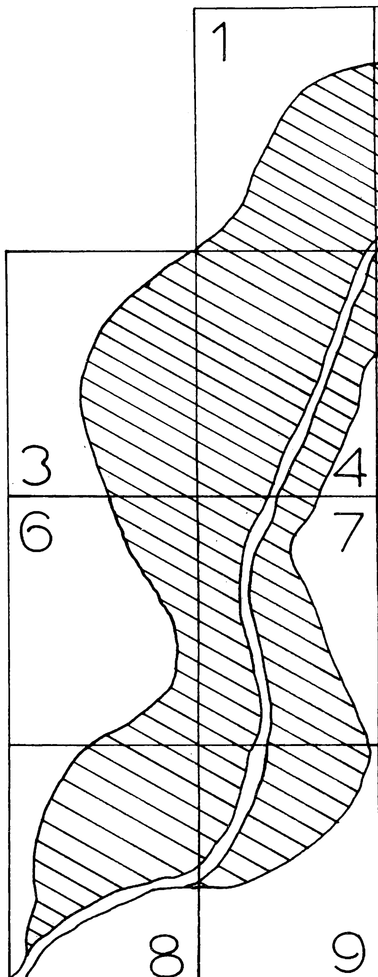

FIGURE 4.—A typical flood plain survey unit with the phreatophyte area indicated by hatching. The rectangles show the coverage of aerial photographs needed for the survey.

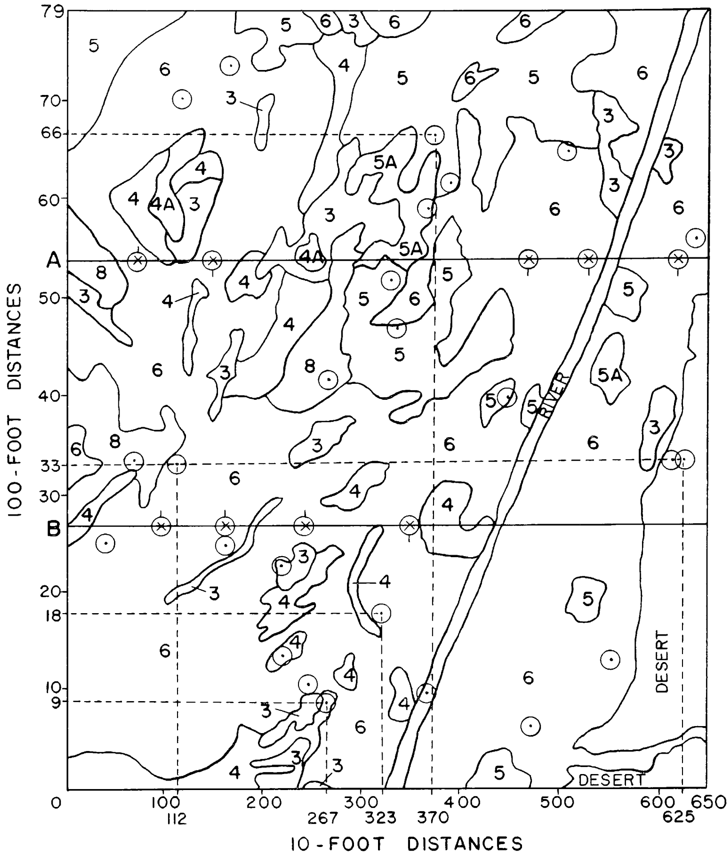

FIGURE 5.—An overlay with corrected type boundaries for the model survey area. The circled dots show random-sampling points as determined by a table of random numbers. Alternate points marked with a circled X on the two cleared access roads could be used if type 6 is too dense a stand for practical entry on foot.

Agriculture Miscellaneous Publication 225 (Munns et al., 1949). The largest and most exhaustive table of random numbers has been prepared by the Rand Corporation (1955). It consists of a million random digits.

2. Prepare a map of the entire reach to be sampled, numbering each section covered by an aerial photograph as in figure 4.

3. On the overlay for each section, mark the horizontal and vertical scales as in figure 5. Assuming that the sampling lines are to be 100

feet long and to run north and south, it would be advantageous to place them not closer than 10 feet apart along the east-west axis. Also, these sampling lines would be spaced 100 feet apart along the north-south axis. Thus, the east-west axis would be divided in tens of feet, and the north-south axis in hundreds of feet.

4. To select the random numbers from the table, start at a point picked at random and read downward or across for the required number of figures. Each sampling point requires three numbers for its location. The first digit selects one of the nine photo overlays shown in figure 4. The second number gives the east-west location of the sampling line. Since these lines are spaced 10 feet apart, 650 possibilities are shown on the horizontal scale of figure 5. The third number gives the location on the vertical scale, which is in 100-foot distances with 79 possibilities.

Figures read off the random-number table should be listed in the following manner. Note that no figures over 9 are included in the first column, none over 650 in the second, and none over 79 in the third.

Overlay number	*Horizontal*	*Vertical*
2	593	29
3	103	51
4	112	33
7	544	28
6	168	08
5	156	64
2	116	37
9	407	66
6	225	74
7	602	74
6	574	11
7	259	56
1	124	46
4	370	66
5	202	15
1	640	40
5	056	00
4	267	09
4	323	18
9	567	33
9	284	75
5	476	66
4	625	33
7	328	78
1	169	12
Etc	Etc.	Etc.

5. Mark these numbers on the overlays in sequence. The first random number in the list is 2–593–29. The "2" places the sampling point in the second rectangle of figure 4. The second number "593" places the point far to the east and "29" would place it about one-third of the way up from the southeast corner. A glance at figure 4 shows that this point is outside of the phreatophyte area and, therefore, must be eliminated. The second figure is 3–103–51. This point is in overlay number 3 and near the southwest corner. Thus, it also is outside and cannot be sampled. The third figure, 4–112–33, is in overlay number 4. This point is located on figure 5 with a dash line extending to the right from the point marked 33 and up from the point marked 112. It is in type number 6.

6. Continue locating random numbers on the overlays until the desired numbers of sampling points are placed in each type and subtype. After sufficient points have been randomly selected for a particular type, subsequent points falling in that type area are not used. For instance, 40 points are needed for type 6, which covers a large area. It is probable that enough of these points would be marked long before sufficient points are located for the smaller subtypes, such as number 4A.

The following numbers on the preceding list fall in overlay number 4:

4–112–33
4–370–66
4–267–09
4–323–18
4–625–33

These are marked with dashed lines from the vertical and horizontal axes in figure 5. Also indicated are 21 other sampling points determined from the table of random numbers by the same procedure.

Alternate Procedure in Dense Brush With Limited Access

The procedure previously described should be followed if possible because it meets the requirements of sound statistical sampling. Some phreatophyte stands, however, are so dense that it becomes impracticable to sample points far from openings, and a random distribution of sampling points through their entire area is unworkable. In this situation a sampling area should be established along such means of access as roads, brushed section lines, and trails (see frontispiece). Preferably the road or other means of access should extend through the type being sampled, with the same type of vegetation on both sides of the access route.

The edge of a cleared field should not be used for sampling unless it is known that the cleared area originally had the same vegetation as the surrounding brush. Even though it might be convenient, sampling heavy brush from the edge of a natural opening, or from an adjacent open type such as grassland, must be avoided. The plant growth and crown cover adjoining the open area is not representative of the stand. The vegetation is larger and the cover more dense, for here sunlight is available to the plant leaves both from the sides and above.

In the model area, east-west lines one-half mile apart have already been cleared for access. These access ways make ideal starting points for a survey if we must sample only a zone of convenience. If, for example, the tamarisk type (No. 6 in fig. 5) cannot be sampled by the standard procedure because of its dense, junglelike character, the access roads would make a convenient starting point. The method of random sampling would be similar, but locations along a line would be chosen rather than throughout the type area. By measurement the access roads intercept type 6 for a distance of about 8.7 inches on the map, which at 6 inches to the mile equals 7,656 feet. With a minimum distance of 10 feet between lines, 765 line locations are possible for this area, or 1,530 sample points if lines are chosen to extend both south and north from the access line. Additional locations are, of course, possible on the other overlays.

The approximate locations of the sampling lines needed for type 6 that were selected from a table of random numbers are marked by circled X's in figure 5. The short perpendicular line indicates in which direction the sampling line is to be extended. The actual start of the sampling line must be far enough from the means of access to avoid disturbance (preferably 100 feet into the brush).

Procedure in Dense Brush Without Practical Means of Access

Some phreatophyte areas to be surveyed not only have a dense, impenetrable cover but also are lacking in roads, trails, or other means of access. In such areas, use of aircraft should be extended to include ocular estimates of cover as well as the mapping of type boundaries described previously. This method was first developed and used by Turner and Skibitzke (1952) of the U.S. Geological Survey in making surveys of phreatophyte vegetation in the Salt River flood plain in Arizona, where they were able to cover 30 square miles in 5 days. As a ground check, Turner and Skibitzke recorded densities along a series of transects and found that the cover densities as mapped from the airplane were very close to those determined on the ground.

Workers using the ocular method must check their estimates periodically, preferably daily, against standard areas of previously determined crown-cover percentages. Essentially, these standards should consist of four or five plots ranging from low to high cover. The height of woody plants and the crown cover in these plots, preferably about an acre in size, should be determined accurately by actual mapping or by a series of line-intercept measurements. The plot should be clearly marked to be readily identified from the air. Mappers should observe the standard test plot from the air before starting each day's mapping.

Collection of Field Data

For efficiency, the sampling points marked on the overlays of the aerial photographs should be scheduled for fieldwork in groups according to location. Thus all sampling lines in a particular area should be measured in sequence by location rather than by type.

In the model survey (fig. 5), if sampling is to start from the west along the lower access road (B), a definite starting point should first be established by driving a stake at the side of the access road as it enters the area mapped by this overlay. It has already been decided that type 6 cannot be sampled except in the zone of convenience along the access roads; therefore, circled points in type 6 in figure 5 will be ignored. The other types and subtypes will be sampled by the standard procedure.

The location of each sampling line is determined by pacing. The point in type 8 north of the access road would be paced out first. The access to this point would be on a diagonal through the relatively open type 4. Then the three lines in type 6 to be extended north from the access would be located, followed by the point in type 3 south of the road.

Some points will be hard to reach, such as the one in the isolated type 4 at about 14 north and 215 east. The best way in this instance would be to work through the brush, without attempting to pace, to the upper edge of the area to be sampled; then pace the indicated distance in the proper compass direction.

Care must be taken to eliminate personal bias. Even if a randomly selected point falls in the thorniest bush in the whole area, that spot must be taken as the start of the sampling line.

The ends of each line should be permanently marked for remeasurement at a future date. Painted metal posts driven in the soil with the base surrounded by rocks are satisfactory. If the lines are in heavy brush, it is well to establish stakes marked with the line number in nearby openings, referenced to the sampling point by compass direction and distance.

Recording of Data

The data from the sampled lines must be recorded in a consistent manner to avoid confusion and errors in interpretation. A hypothetical 100-foot profile of mixed tree-shrub-grass vegetation is shown in figure 6 to illustrate problems facing fieldworkers. The species are recorded by use of standard symbols.[7]

For each sampling line a form similar to figure 7 should be filled out. The following explains the kinds of information to be recorded.

Location.—Information should include notes on the general area as well as an identification of the aerial photograph, such as Pecos River, McMillan Delta, aerial photograph number 10–181. Also, if possible, the official survey description should be given.

Vegetation type.—Name the type and refer to the number used on the aerial photograph or corrected overlay.

Soil texture.—Use standard terminology such as sand, sandy loam, or clay loam. Note gravel or any surface efflorescence.

Remarks.—Include such pertinent information as: (1) Past use of herbicides, (2) any clearing or burning, (3) depth to water table determined from nearby ground-water wells, if any. If water levels are less than 8 feet below the surface, use a soil auger at representative locations.

Woody vegetation—layer and species.—Each tree or shrub or group of the same species is recorded from the point where the tape first intercepts the crown to the point where the intercept ends.

Trees.—Heights of trees and their crown depth are best measured by use of a topographic Abney hand level with the scale reading in percent rather than degrees. If the level is graduated in percent, the observer should pace or measure out 100 feet from the base of the tree (in dense stands, 50 feet can be paced out and the Abney reading divided by 2), sight to its top, read the height above eye level directly from the scale, and then read on the scale the distance from the eye level to the ground. The two readings added together will give the total height of the tree. The crown depth is determined by reading the heights of the upper and lower edges of the crown in reference to eye level and subtracting the lower from the upper.

Shrubs.—For height of shrubs, a rod marked in feet is suggested for measurement. If the living parts of the crown do not extend to the ground, both total height of shrub and thickness of crown canopy should be measured.

Ground cover.—Intercept of the important species of grass and herbs and the distance occupied by litter, rocks, and bare soil should be recorded. It is well to record average height and character (grass sod, etc.) of dominant

---

[7] The symbols used in figures 6 and 7 are:

Pofr–2	Fremont cottonwood (*Populus fremonti* S. Wats.)
Tape	Fivestamen tamarisk
Plse	Arrowweed pluchea
Cyda	Bermudagrass (*Cynodon dactylon* (L.) Pers.)
Bagl	Seepwillow baccharis

These symbols are from "Check list of native vegetation in Southwest Region," U.S. Forest Service, Region 3, Albuquerque, N. Mex.

species. Detailed measurements of herbaceous cover are not needed in most surveys if the final objective is the estimation of water losses. However, if utilization of herbaceous cover by livestock will be a factor in the future management of the area being surveyed, this justifies more detailed measurements using range survey techniques. Brown (1954), National Academy of Sciences—National Research Council (1962), and Phillips (1959) discuss and summarize the more important sampling methods and their application to range or herbaceous covers.

Notes.—Record such pertinent information on the vegetation as condition and vigor, including any dieback or especially rapid growth. Also note any insect infestations or injury by disease. Nearby individuals of important species which are not included in the sampling line can be noted here.

Data from the line in figure 6 are transcribed on the sample form (fig. 7). The distance 0 to 15 feet is dominated by a Fremont cottonwood tree 30 feet high having a crown depth of approximately 20 feet. Bermudagrass occurs from 8 to 12 feet. A 10-foot tamarisk shrub occurs from the 10- to 15-foot intercepts, an 8-foot tamarisk from 15 to 20 feet, 20 to 24 feet is a stretch of bare soil with no vegetation cover, etc.

Data Computations

Table 4 gives a summary of the readings taken from the hypothetical sampling line. Fifteen feet of line are covered by trees (Fremont cottonwood), shrubs cover 65 feet, and open areas with bare ground or grass make up 33 feet. Because this is a 100-foot sampling line, these figures are used directly to indicate cover percent.

TABLE 4.—*Summary of data from the line intercept shown in figures 6 and 7*

Layer and species	Total height	Depth of crown	Intercept distance	Cover by layers
	Feet	*Feet*	*Feet*	*Percent*
Tree:				
Cottonwood	30	20	15	15
Shrub:				
Tamarisk	10	6	5	
	8	6	5	
	12	8	6	
	13	9	10	
	7	5	12	
	17	15	11	
Total tamarisk			49	
Arrowweed	7	5	7	
Seepwillow	8	5	9	
Total shrub				65
Ground cover:				
Bermudagrass			4	
			9	
Total				13
Bare soil			4	
			1	
			3	
			12	
Total				20

The average height is computed from individual distance and height figures. For example, cottonwood where it occurs along this line has an average height of 30 feet and crown thickness of 20 feet. The tama-

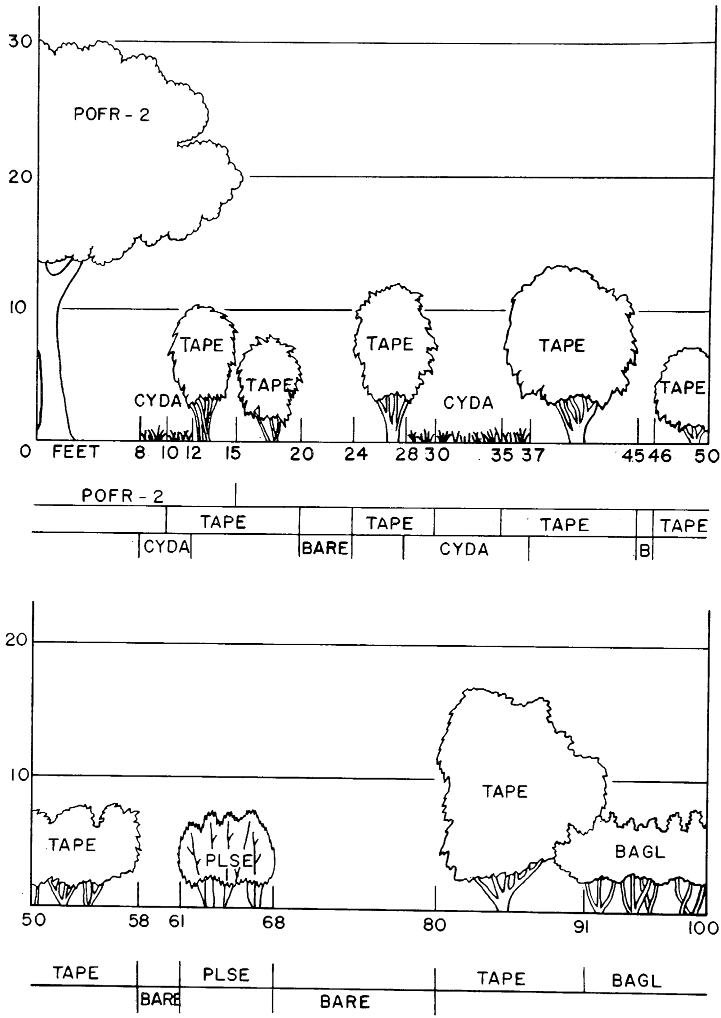

FIGURE 6.—Hypothetical sampling line in mixed tree-shrub-grass vegetation.

SAMPLING LINE DATA

Agency________ Observers________ Date______

Location________

Section____ T____ R____ Base line and meridian________

Vegetation type________ Line No.____ Length____

Soil texture________ Elevation____

Remarks________

Woody Vegetation					Ground Cover			
Layer and Species	Intercept From	Intercept To	Height	Crown Depth	Species or Type	Intercept From	Intercept To	Remarks
Trees								
Pofr-2	0	15	30	20	Cyda	8	12	Sod, 6"
					Bare Soil	20	24	
					Cyda	28	37	Sod, 6"
Shrubs					Bare Soil	45	46	
Tape	10	15	10	6	Bare Soil	58	61	
Tape	15	20	8	6	Bare Soil	68	80	
Tape	24	30	12	8				
Tape	35	45	13	9				
Tape	46	58	7	5				
Plse	61	68	7	5				
Tape	80	91	17	15				
Bagl	91	100	8	6				

Notes

A few young cottonwood trees 5 to 10 feet high just east of the line are growing vigorously.

FIGURE 7.—Form with data from sampling line shown in figure 6.

risk average height would be computed by multiplying each height group and distance. From table 4, 5 feet of line with 10-foot tamarisk equals 50, 5 feet of line with 8-foot tamarisk equals 40, etc., adding to a total of 563 for the line shown in figure 6. To get the average height for a species as it occurs in an entire vegetation type, sum all height-times-feet values for that species and divide by the total feet, as in the following example using four of the lines.

	Feet of Line	*Height×Feet*	
	49	563	(Line in fig. 6)
	50	610	
	20	180	
	100	1,300	
Total	219	2,653	

The average height for the tamarisk in the type under consideration is 2,653/219=12.1 feet. The same computation is then carried on for tamarisk crown depth and for the other species in the type.

Reliability of the Data

It is always desirable to check the actual reliability of data collected by any random-sampling method. The procedures outlined by Canfield (1942) are closely followed in this section. No attempt is made here to explain the derivation of the terms used. If the reader wishes more information, he should refer to Canfield or to any standard textbook on statistics, such as Snedecor (1956).

The reliability of a random sampling in estimating the true mean of a population varies in relation to the deviations of the individual measurements from the mean. The *standard deviation* is an expression of the magnitude of these deviations. As the deviations increase, the number of samples necessary to obtain a given precision also increases.

In determining the number of lines to sample in the model survey, we decided upon a specified error for each type-density class. We should test our data to determine whether we achieved this degree of precision by computing a value called the *standard error* of the mean. If the mean of the data is 50 and it is desired to have a precision of ± 10 percent of the mean, the standard error should not be greater than ± 5.0. The smaller the value of the standard error, the greater is the reliability of the data.

However, a value of plus or minus twice the standard error is usually used to test reliability when sample size is greater than 15. This gives greater assurance that the survey has achieved its goal of precision. In the example in the preceding paragraph, the standard error should not be greater than 2.5. Twice 2.5 equals 5.0, which is 10 percent of the mean of 50.

Our problem is to determine whether the number of lines established by use of the nomograph adequately samples the vegetation cover to the error specified for the type. If twice the standard error is equal to or less than the specified error, we have achieved our goal of reliability. If twice the standard error is more than the specified error, then insufficient lines were measured. Therefore, we can, by using the statistical values obtained, determine the number of lines needed to reach our specified goal.

Method for Computing Reliability of Data

In the model survey, we can determine for each type and subtype whether we have attained the precision desired or whether more sampling lines are needed.

The computations for each type can follow the long method shown in table 5.

TABLE 5.—*Sample computation of standard deviation and standard error by use of the long method*

Line number, N (1)	Percent crown cover, X (2)	Deviations, x (3)	Deviations, x (4)	Deviations squared, x^2 (5)
1	97	+17		289
2	62		−18	324
3	67		−13	169
4	69		−11	121
5	93	+13		169
6	69		−11	121
7	93	+13		169
8	84	+4		16
9	91	+11		121
10	55		−25	625
11	82	+2		4
12	91	+11		121
13	100	+20		400
14	68		−12	144
15	79		−1	1
	Σ=1, 200 Mean=80	+91	−91	Σ=2, 794

1. The mean of the crown-cover percent is computed as 80 percent (column 2).
2. The mean is subtracted from each observation to give the deviations of the individual reading from the mean (columns 3 and 4).
3. These deviations are squared and added (column 5).
4. The standard deviation is then computed by the formula:

$$\text{Standard deviation (SD)}=\sqrt{\frac{\text{Sum of squared deviations}}{\text{Number of observations less 1}}}=\sqrt{\frac{\sum x^2}{N-1}}$$

Using this formula:

$$SD=\sqrt{\frac{\sum x^2}{N-1}}=\sqrt{\frac{2{,}794}{14}}=\sqrt{199.5714}=14.13$$

In most cases the standard deviation can be more readily computed by the following shortcut formula (table 6), especially if there are a large number of values and if a calculator is available:

$$\text{Standard deviation (SD)} = \sqrt{\frac{\sum X^2 - \frac{(\sum X)^2}{N}}{N-1}}$$

Using the data computed in table 6:

$$SD = \sqrt{\frac{98{,}794 - \frac{(1{,}200)^2}{15}}{14}} = \sqrt{\frac{98{,}794 - 96{,}000}{14}} = \sqrt{\frac{2{,}794}{14}} = 14.13$$

TABLE 6.—*Sample computation of standard deviation by use of the shortcut or calculator method*

Line number, N	Percent crown cover, X	Crown cover squared, X^2
1	97	9, 409
2	62	3, 844
3	67	4, 489
4	69	4, 761
5	93	8, 649
6	69	4, 761
7	93	8, 649
8	84	7, 056
9	91	8, 281
10	55	3, 025
11	82	6, 724
12	91	8, 281
13	100	10, 000
14	68	4, 624
15	79	6, 241
	Σ=1, 200 Mean=80	Σ=98, 794

5. The standard error is calculated by the formula:

$$\text{Standard error (SE)} = \frac{\text{Standard deviation}}{\text{Square root of number of observations}}$$

$$SE = \pm\frac{14.13}{\sqrt{15}} = \pm 3.65$$

6. To check on precision obtained, the standard error of ±3.65 is multiplied by 2 to equal ±7.30. In terms of percent of mean:

$$\text{Twice standard error} = \frac{7.30}{80} = 9.1 \text{ percent of the mean}$$

7. To determine how many lines would actually be needed for a specified precision, we use the standard error formula. Our desired reliability requires that twice the standard error should not be greater than the specified error (expressed in percent of mean). Thus to derive the number of lines needed, the standard error formula is used as follows:

$$\text{As standard error} = \frac{\text{SD}}{\sqrt{\text{N}}} \text{ then}$$

$$\text{Specified error} = \frac{2 \text{ SD}}{\sqrt{\text{N}}} \text{ or}$$

$$\sqrt{\text{N}} = \frac{2 \text{ SD}}{(\text{Specified error})} \text{ or } \text{N} = \frac{(2 \text{ SD})^2}{(\text{Error})^2}$$

Thus, the number of needed observations equals

$$\frac{\text{The square of twice the standard deviation}}{\text{The square of the specified percent of the mean}}$$

Using the same data as in paragraph 4 and table 5, the computation of needed lines (N) for a specified precision of 10 percent of the mean is as follows:

$$\text{N} = \frac{(2 \times 14.13)^2}{(8.0)^2} = \frac{798.6276}{64} = 12.48 \text{ or } 13$$

Thirteen sampling lines would give the desired precision of 10 percent of the mean.

8. Because the criterion of twice standard error for estimation of precision becomes inaccurate if the number of samples is less than 30, adjustments of number of lines needed should be made for smaller sample sizes. For practical purposes, always sample 15 or more lines. If 15 to 25 lines are indicated, increase the sample size by 10 percent.

Analysis of Model Survey

The first analysis of the field data should be the statistical checks previously outlined to determine the reliability of the survey and whether additional lines must be run to adequately sample any of the types. Tables 7 and 8 give the statistical values determined by the analysis of data used in the model survey. These data indicate the reliability of our survey and tell us if we have reached our desired precision.

Tamarisk

The goal for sampling the tamarisk type was to obtain a precision of 10 percent of the mean. The nomograph indicated that 29 sampling lines would achieve this objective. Forty lines, however, were decided upon. The analysis of data showed that twice the standard error was 9.6 percent of the mean, which indicates that the desired precision of 10 percent was obtained. If we had sampled only 30 lines, it would have been necessary to run additional lines because the analysis shows that 37 lines were necessary to obtain the desired 10 percent precision.

TABLE 7.—*Summary of statistical values for types with one dominant species*

Item	Tamarisk	Arrowweed		Mesquite		Saltbush
		Open	Dense	Open	Dense	
Type number	6	5	5A	4A	4	3
Selected precison expressed in percent of mean	10	13	12	20	13	20
Number of lines selected	40	30	20	15	15	20
Mean crown-cover percent	61. 3	34. 8	63. 6	56. 3	83. 3	42. 0
Standard deviation	18. 51	14. 80	16. 77	15. 50	16. 92	20. 54
Standard error	±2. 93	±2. 70	±3. 75	±4. 00	±4. 37	±4. 59
Twice SE in percent of mean	9. 6	15. 5	11. 8	14. 2	10. 5	21. 9
Lines needed for:						
10% error	37	72	28	31	[1] 17	96
15% error	[1] 16	32	(2)	(2)	(2)	43
20% error	(2)	[1] 18	(2)	(2)	(2)	[1] 24

[1] Increase by 10 percent.
[2] Less than 15 lines indicated; raise to 15.

TABLE 8.—*Summary of statistical values for tamarisk-seepwillow type (No. 8)*

Item	Tamarisk	Seepwillow	Total cover
Allowable error in percent of mean			15
Number of lines selected	20	20	20
Mean crown-cover percent	41. 5	28. 5	73. 2
Standard deviation	15. 80	10. 39	14. 22
Standard error	±3. 53	±2. 32	±3. 18
Twice SE in percent of mean	17. 0	16. 3	8. 7
Lines needed for:			
10% error	58	53	[1] 15
15% error	26	[1] 24	(2)
20% error	(2)	(2)	(2)

[1] Increase by 10 percent.
[2] Less than 15 lines indicated; raise to 15.

Tamarisk-Seepwillow

Because tamarisk and seepwillow were equally important in this type, the crown-cover data for the two species were analyzed separately in addition to the analysis for the total crown cover (table 8). Results showed that the greatest number of sampling lines would be needed to achieve the desired reliability in crown-cover percent of tamarisk. In practice we achieved a precision in the field data of 17.0

and 16.3 percent of the means for the two species and 8.7 percent for the total cover. This exemplifies the fact that many more lines are needed in a mixed cover to obtain the desired precision for the codominant species individually than for the total cover.

In most surveys, if the species are fairly similar in water consumption, lower reliabilities for the individual species would be acceptable and the total cover could serve as the guide in fixing the desired number of sampling lines.

Arrowweed

The 30 lines sampled in open arrowweed (table 7) obtained a value of twice the standard error equal to 15.5 percent of the mean, which did not achieve the desired 13 percent. Forty or more lines would have been needed to accomplish this.

In dense arrowweed, the standard error was computed to be ±3.75. Twice this value is equal to 11.8 percent of the mean. Thus, the sampling achieved the desired 12 percent precision.

In an actual survey, a decision would have to be made whether to accept the lower precision for the open arrowweed or to select more sample points and run additional sampling lines.

Mesquite

The sampling of both open and dense mesquite was more than adequate. The standard error for open mesquite was ±4.00, and twice the SE equals 14.2 percent of the mean. The dense mesquite had a standard error of ±4.37; twice this equals 10.5 percent of the mean. Inasmuch as we had chosen a desired precision of 20 percent for open mesquite and 13 percent for dense, our sampling was successful. These results were to be expected because more lines were run than the numbers indicated in table 3.

Saltbush

In contrast to mesquite, the 20 lines selected for saltbush did not achieve the desired 20 percent precision because the variability was greater than expected. The standard error was ±4.59 and 2 SE equals 21.9 percent of the mean. Twenty-four lines would have been needed to achieve the desired 20 percent precision. Again, in a real survey this would require a decision whether to measure extra lines to improve reliability of sampling.

Summation of Type Characteristics

After the data from the sampling lines taken in all component types are determined to be of sufficient reliability, the data on crown cover, height of trees and shrubs, and crown depth are averaged for each vegetation type. These averages can then be applied to the areas of the type.

The areas are obtained directly from the aerial photograph, either with a transparent dot or grid overlay or a planimeter (Society of American Foresters, 1955). An overlay with dots arranged in evenly spaced rows of 10 dots to the inch in both dimensions, providing 100 dots per square inch, is easy to use. The relation of dots and area on the photograph must be determined. If the scale of the aerial photographs is 4 inches to the mile, then 1,600 dots equal 1 square mile, or one dot equals 0.4 acre.

Characteristics of the phreatophyte vegetation can be expressed thus: Number of acres of a particular type averaging a certain crown-cover percent, average height, and crown thickness. For example: 250 acres of tamarisk, 72 percent crown cover, averaging 10 feet in height with depth of crown 7 feet; with associated seepwillow at 5 percent cover, average height 8 feet with depth of crown of 6 feet; and cottonwood, 3 percent of the cover averaging 32 feet in total height with depth of crown of 16 feet.

Provision for Future Surveys

All surveys of phreatophyte vegetation should be carried on in such a manner that resurveys can be made. Ground reference points should be described carefully for later observations. Wherever possible, sampling lines should be permanently marked and referred to established points such as bench marks or section corners.

Information on all surveys should be entered on forms similar to figure 8 and sent to the Chairman of the Phreatophyte Subcommittee or to Rocky Mountain Forest and Range Experiment Station, Arizona State University, Tempe, Ariz., for inclusion in the Subcommittee Library. It is desirable also to send reference photographs with carefully indicated camera points that can be relocated and the photograph repeated at some future date.

MAJOR AREAS OF PHREATOPHYTE GROWTH AND METHODS OF SAMPLING

In the West, ground water conditions favorable for the growth of phreatophytes occur on flood plains and reservoir deltas, in areas surrounding playas, and along streambanks.

Flood Plains and Reservoir Deltas

Most streams and rivers, after emerging from the mountains to form the major valleys, have broad and well-developed flood plains. Here a ground water reservoir is generally present and maintained either by inflow from the sides of the valley or seepage from the stream. The depth to the water table is usually shallow, and as a result phreatophytes develop as a wide band of vegetation. This band covering the flood plain may be several miles wide.

In the Southwest, this vegetation now contains large proportions of fivestamen tamarisk (fig. 9), associated with seepwillow, cottonwood, mesquite, arrowweed, and willow (fig. 10). Saltbush (*Atriplex* spp.) and pickleweed (*Allenrolfea occidentalis* (S. Wats.) Kuntze) are common in the more alkaline soils. Grasses such as Bermudagrass, inland saltgrass (*Distichlis stricta* (Torr.) Rydb.), and alkali sacaton (*Sporobolus airoides* Torr.) are often abundant.

Inventory of Existing Survey Data
Phreatophyte Vegetation
Spread, Composition, or Density

Agency that made survey____

Date of survey____

Location of area surveyed:

State__________________ County or counties_____________________

Sections______, T______, R______, Base line and meridian___________

River____

from_______________________ to ___________________________

Other included streams or areas________________________________

Description of surveyed area (such as width of flood plain or channel, relation to reservoir delta, and other distinctive features)______

____

____

____

Principal species of trees and shrubs___________________________

____

____

Survey method used____

Describe method used, if different from standard_________________

____

____

____

Other data taken (such as soil, herbaceous cover, water table depth, salinity, etc.)____

____

____

Where are the field data filed?_________________________________

Was a summary of the data made?_____________________________

If so, where filed?______________________________________

Were maps of the vegetation prepared?_________________________

Were water-loss estimates made?_____________________________

Publications and reports that include either the data or the summary

____

____

Signed__________________ For (agency)_____________________

Address____

Return completed form to the chairman of the Phreatophyte Subcommittee or to
Rocky Mountain Forest and Range Experiment Station
U.S. Forest Service
Arizona State University
Tempe, Arizona 85281

FIGURE 8.—Sample form for reporting surveys.

FIGURE 9.—Aerial view of the Gila River near Buckeye, Ariz., shows the dense, almost impenetrable stand of tamarisk that has invaded the flood plain. (U.S. Geological Survey photo W–58–144.)

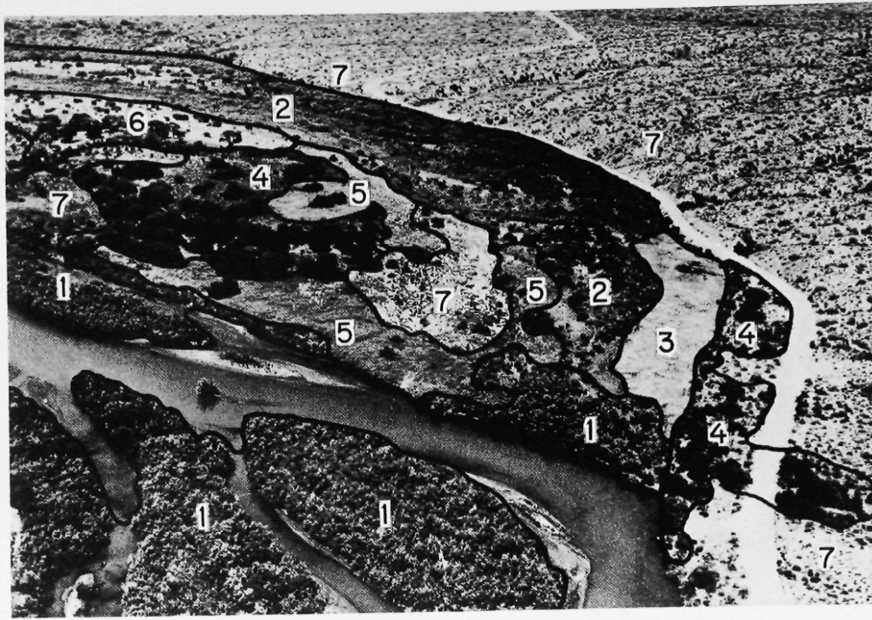

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FIGURE 10.—Vegetation growing along the Salt River near Granite Reef Dam, Ariz., includes: (1) Tamarisk and associated seepwillow on the islands and along the river in the foreground; (2) tamarisk and Bermudagrass (in the old river channel parallel to the road); (3) cattail (*Typha* spp.); (4) mesquite; (5) arrowweed; (6) cottonwood; and (7) desert scrub. (Original photograph courtesy of Donald Dockins.)

The delta areas of a reservoir usually have a shallower water table, but the vegetative cover is much the same as on flood plains of a stream. As the deltas encroach on the reservoir, so the phreatophytes encroach on the delta. As a rule, both flood plain and delta areas are subject to periodic inundation.

The vegetation of flood plains and reservoir deltas can usually be surveyed by the standard procedure outlined in the first section. Some areas, however, will have such dense cover that the alternate method of selection of sample points in heavy brush suggested on page 16 may be more suitable. Other inaccessible areas of dense cover may have to be surveyed by ocular estimates and mapping from aircraft (p. 17).

Playas

In the Great Basin and other parts of the arid Southwest, there are numerous interior drainage basins of which the playa is the central part. Depending upon the position of the water table, the playa may be dry or wet. The water table occurs at great depth under dry playas and the vegetation surrounding them is xerophytic.

The water table under wet playas is at or near the land surface. Surrounding these are zonal arrangements of vegetation, with the shallowest rooted, and the most salt tolerant, near the playa and the deeper rooted farther out and upslope (fig. 11). A typical arrangement of vegetation upslope from a playa in the Great Basin is pickleweed, saltgrass, black greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.), rabbitbrush (*Chrysothamnus* spp.) and the xerophytes, such as sagebrush (*Artemisia* spp.). If the water is not too saline, willow may occur along the margin. In many playa valleys, greasewood occupies wide bands (fig. 12).

As playas are flat areas with open vegetation, the standard procedure for surveys can be used to good advantage.

Streambanks

Perennial and near-perennial mountain streams have characteristic streambank vegetation consisting of alders (*Alnus* spp.), cottonwoods (*Populus* spp.), willows, and other species, usually deciduous (fig. 13). There is never a lack of water in these sites, for even if the stream should stop flowing for a brief period in the growing season, moisture would be available from ground water.

Intermittent streams that have water flowing during only part of the growing season and may not have abundant ground water supplies during dry periods are characterized by various types of vegetation such as evergreen oaks (*Quercus* spp.), sycamore (*Platanus* spp.), cottonwood, willow, and many other species (fig. 14). In the Southwest, these streams merge into desert washes where mesquite and other deeply rooted desert trees and shrubs are found. Streamflow occurs only rarely, generally as the result of high-intensity but short-duration rainstorms, and ground water usually occurs at considerable depth.

Surveys of the streambank vegetation would generally follow the standard procedure. However, the narrow bands of vegetation which

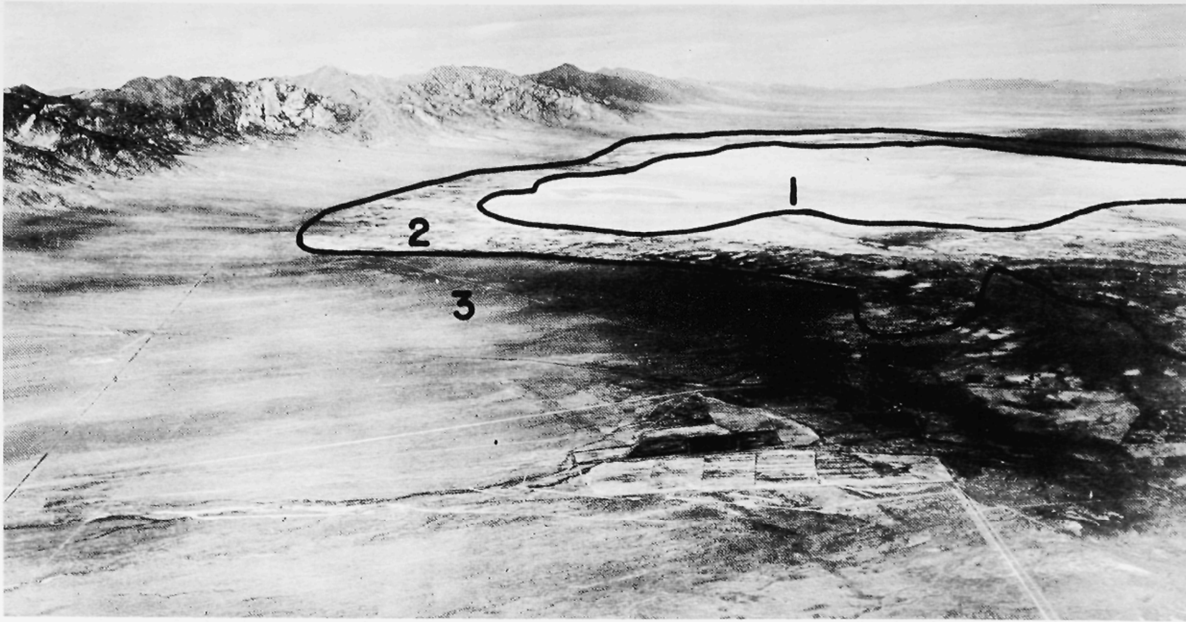

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FIGURE 11.—Toiyabe Range and central playa in Big Smokey Valley, Nev. (1) The wet playa with a small area to the left where the water table is at the surface, (2) the surrounding zone of phreatophytes composed of saltgrass, common reed (*Phragmites communis* Trin.), black greasewood, and rabbitbrush, with clumps of willow and buffaloberry (*Shepherdia* spp.) near the outer edge, and (3) the desert xerophytes. (Original photograph by U.S. Geological Survey.)

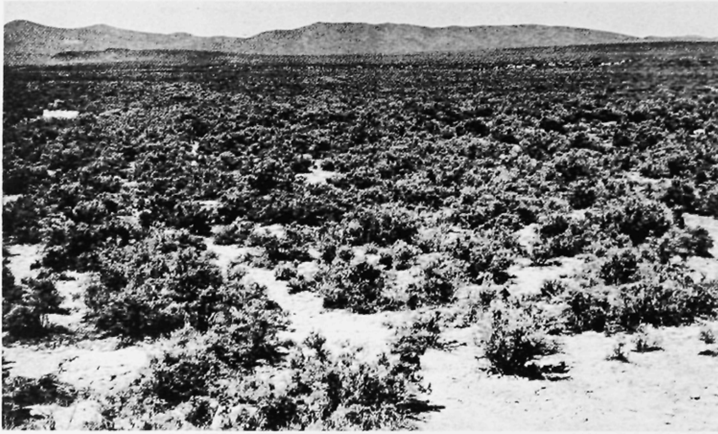

FIGURE 12.—Typical view of a pure stand of black greasewood in the Humboldt River Valley near Winnemucca, Nev. Height of the plants ranges between 2 and 3 feet. (U.S. Geological Survey photo.)

are common in mountain areas and in desert canyons are often not best sampled by line intercepts. Circular plots selected randomly can be substituted. A one-fifth-acre plot should be a satisfactory size. All procedures developed for line intercepts would apply. Data taken on the circular plots can include number of trees or shrubs, basal area, depth of crown, and even estimates of crown cover.

SUMMARY

Phreatophyte vegetation seriously affects water supplies in arid and semiarid regions. Knowledge of the extent and nature of the vegetation cover is needed as a basis for planning treatments of the vegetation and estimating the potential water savings and other effects. Surveys of the vegetation require an economical sampling scheme that can be repeated and will yield data that are precise enough to be reliable. Such a scheme is described and the seven steps necessary in a proper survey are explained.

1. Assemble aerial photographs and become familiar with the survey area and its important species.
2. Map vegetation types on the aerial photographs and refine the type boundaries by observation from aircraft.
3. Determine number of sampling lines.
4. Develop a random-sampling system.
5. Collect field data from the randomly selected points or lines, to be permanently marked.
6. Determine the reliability of the field data.
7. Summarize the data.

Possible variations in the scheme that can be used where the standard method is not completely adaptable are presented, and their applicability in the various phreatophyte types is stated.

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FIGURE 13.—Alders growing along Sycamore Creek near Payson, Ariz.

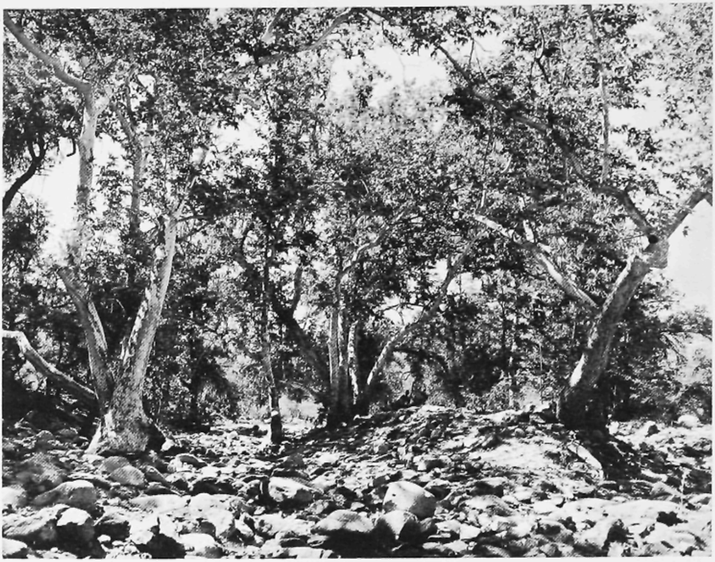

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FIGURE 14.—Sycamores growing along Sycamore Creek near Sunflower, Ariz.

GLOSSARY

Crown cover.—The green canopy of leaves, twigs, and branches of an individual tree or shrub or a stand of woody plants.

Crown-cover percent.—The part of the ground surface shaded by the green canopy composing the crown cover.

Crown depth.—The depth or thickness of the green canopy of an individual tree or shrub or a stand of woody plants.

Density.—Number of individuals of a species or group of species per unit area. "Dense" is sometimes used to designate amount of cover; thus "dense cover" is one which is hard to walk through or is impenetrable, as opposed to an "open cover."

Ground cover.—The material on the surface of the ground, including living herbaceous cover, dead organic material, rocks, gravel, or bare soil.

Line-intercept or line-interception method.—A procedure for sampling vegetation based on the measurement of the intercept of all plants occurring along randomly selected sampling lines. "Transect" is in part synonymous with line intercept, but transects are usually of a specified width.

Phreatophyte.—A plant that grows where its roots can reach ground water or the capillary fringe above a water table.

Sampling line.—Any line between two points randomly selected for measurement of the crown intercepts.

Type.—A plant community including one or several dominant species, such as tamarisk type or tamarisk-seepwillow type. In this publication types have been divided into subtypes on the basis of openness of cover.

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